MUON Collider Collaboration Meeting

International MUON Collider Collaboration

11–14 Oct 2022
CERN
Europe/Zurich timezone

Progress of the Superconducting Magnet R&D For Future Accelerators

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for the superconducting magnet group at IHEP

Oct 12 2022

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Institute of High Energy Physics, CAS

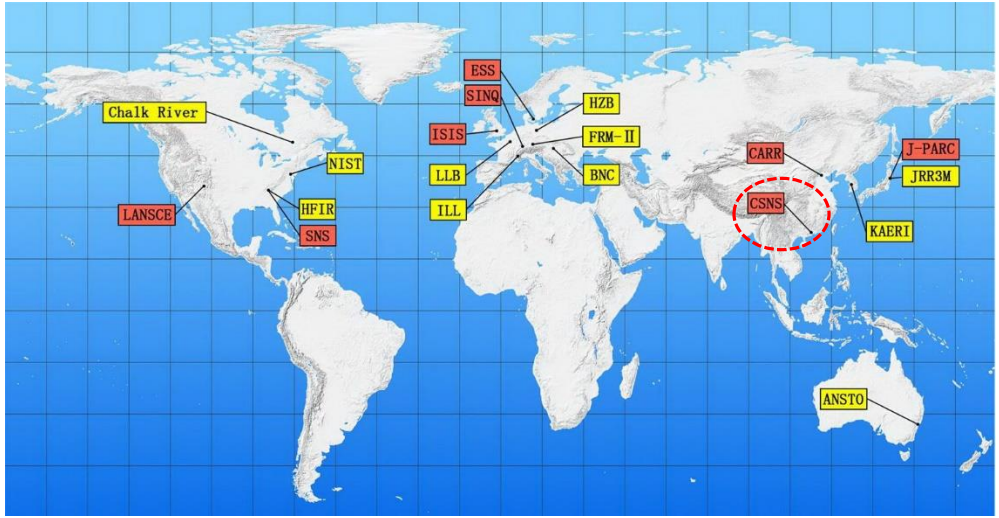
中科院高能所超导磁体组
Superconducting Magnet Group, IHEP CAS

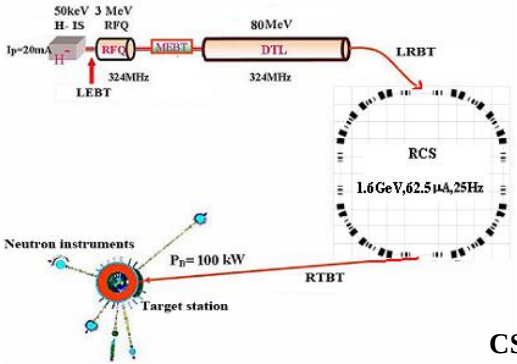
Outline

- Status of the magnet R&D for EMuS at CSNS
- Status and roadmap of the high field model dipoles
- Status and outlook of the IBS technology
- Summary

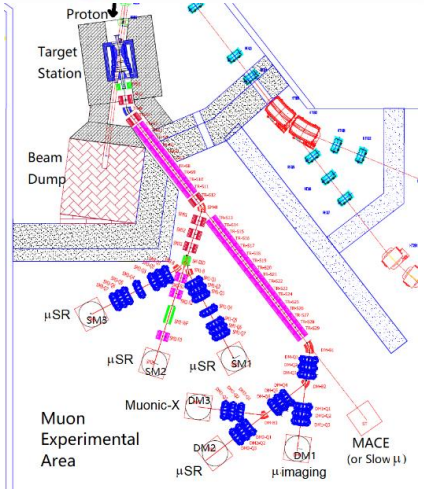
Experimental Muon Source (EMuS) at CSNS

- **CSNS**: A pulsed neutron source facility of 100 kW in beam power, located in Guangdong province of China
- **EMuS**: A muon facility provides intense muon beams: surface muons, decay muons, high momentum muons and slow muons.
- **Capture solenoid** for Emus under development now.





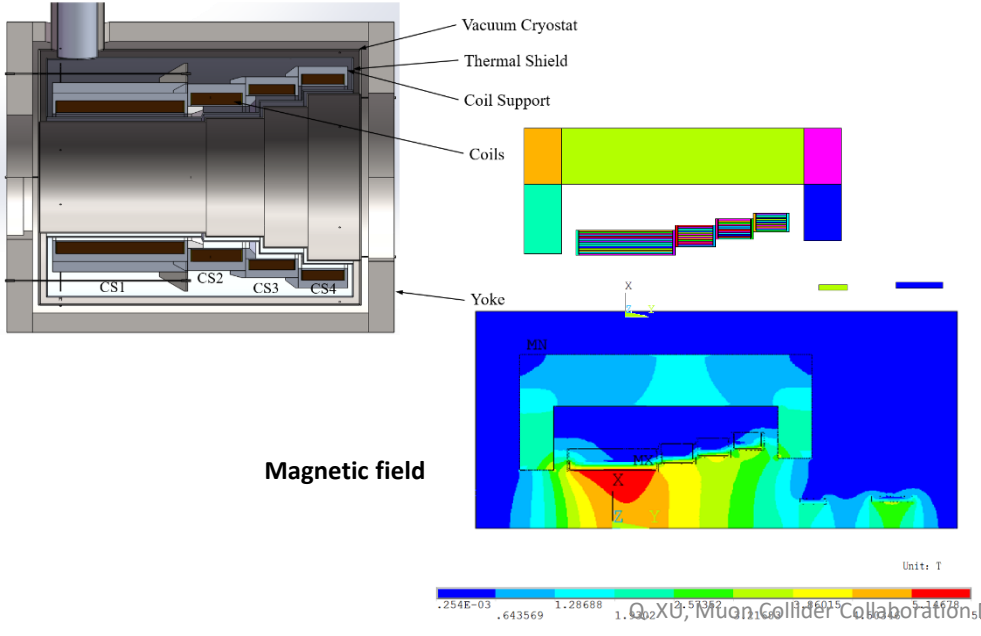
CSNS accelerator



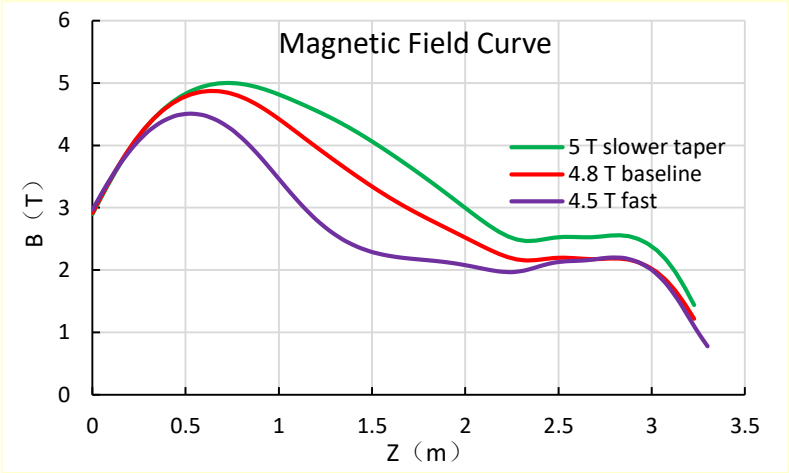
EMuS scheme layout

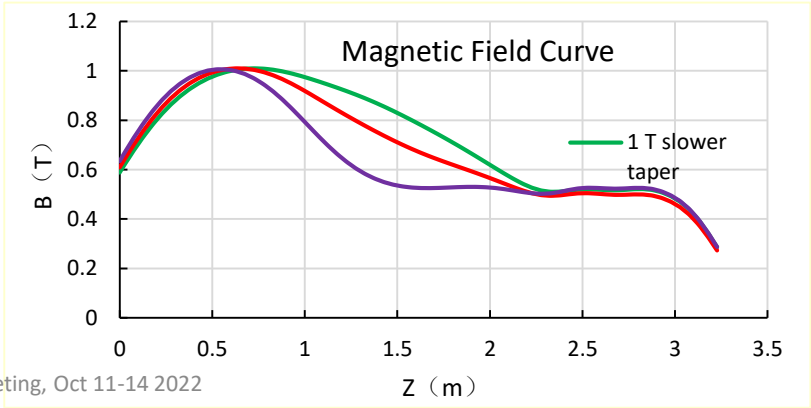
Capture Solenoid for EMuS

- Generates magnetic field : 5 T ~2.7 T, 4.8~2.5 T , 4.5 T ~2.5 T for decay muons, 1 ~0.5 T for surface muons
- Neutron flux: 1.7e21 n/m^2/y



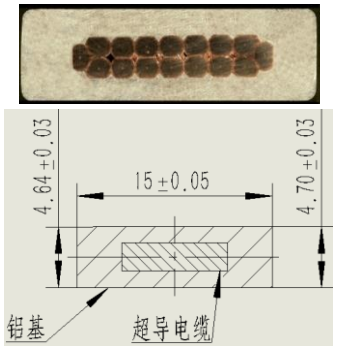
Magnetic field

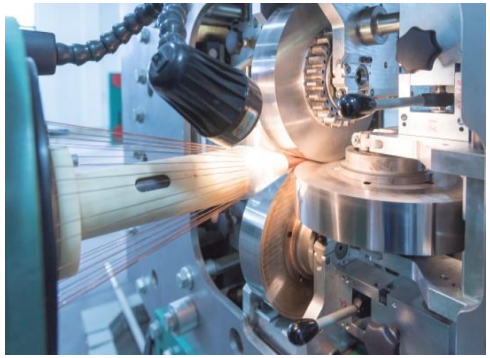


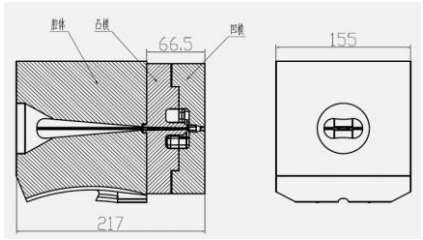


Capture Solenoid for EMuS

Fabrication of the Al-stabilized Rutherford Cable

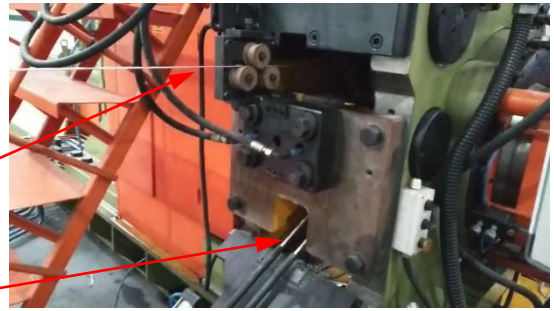






Rutherford cable

Al rod

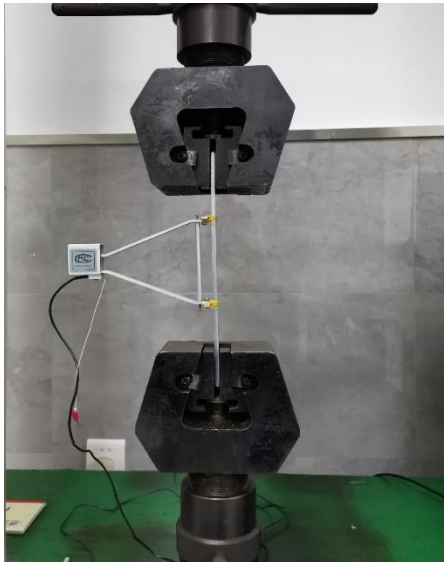


Al-stabilized cable

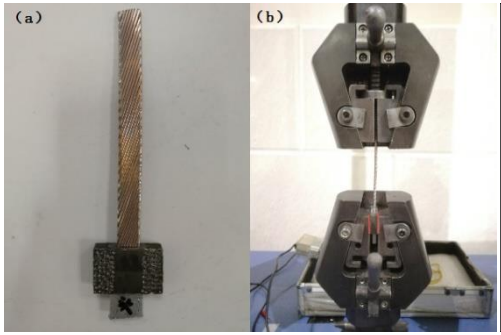
Capture Solenoid for EMuS

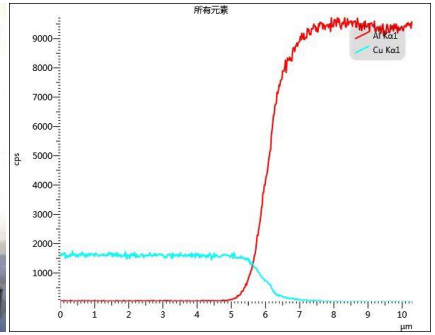
Mechanical Properties of the Al-stabilized Cable

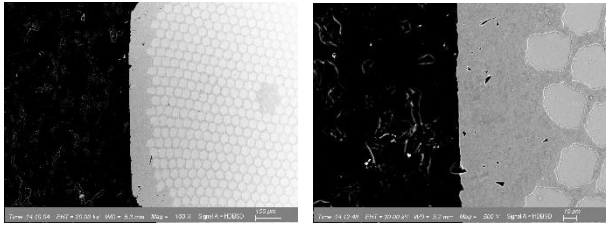
- Yield strength： >150 MPa
- Shearing strength： >20 MPa
- Strand Ic > 1350 A @ 4.2 K， 5.5 T



Yield strength test





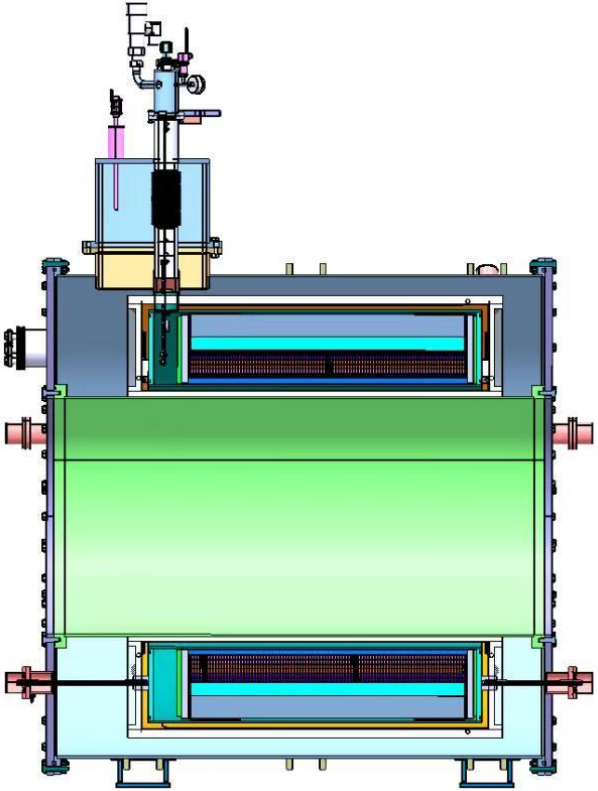


Shearing strength test

Sample for I_c test

Capture Solenoid for EMuS

Manufacturing of the Prototype Solenoid



Winding site

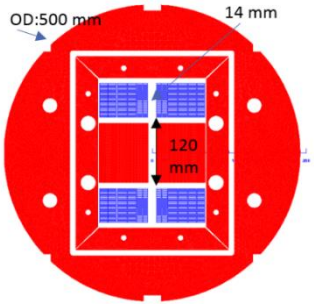
VPI

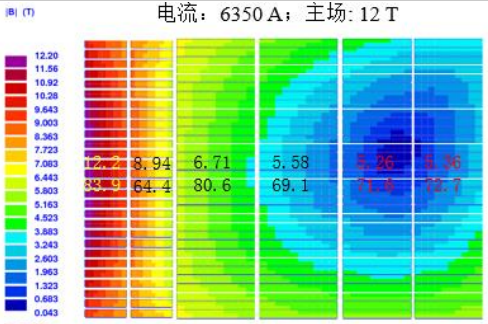
Coil winding

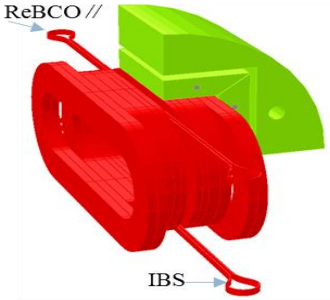
Post-treatment

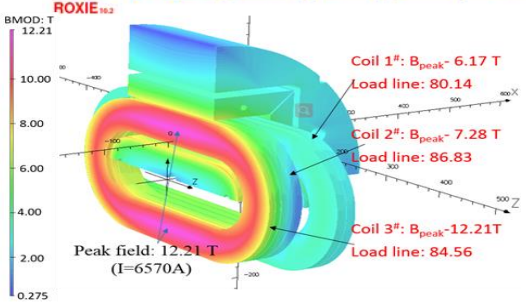
R&D of the High Field Model Dipoles

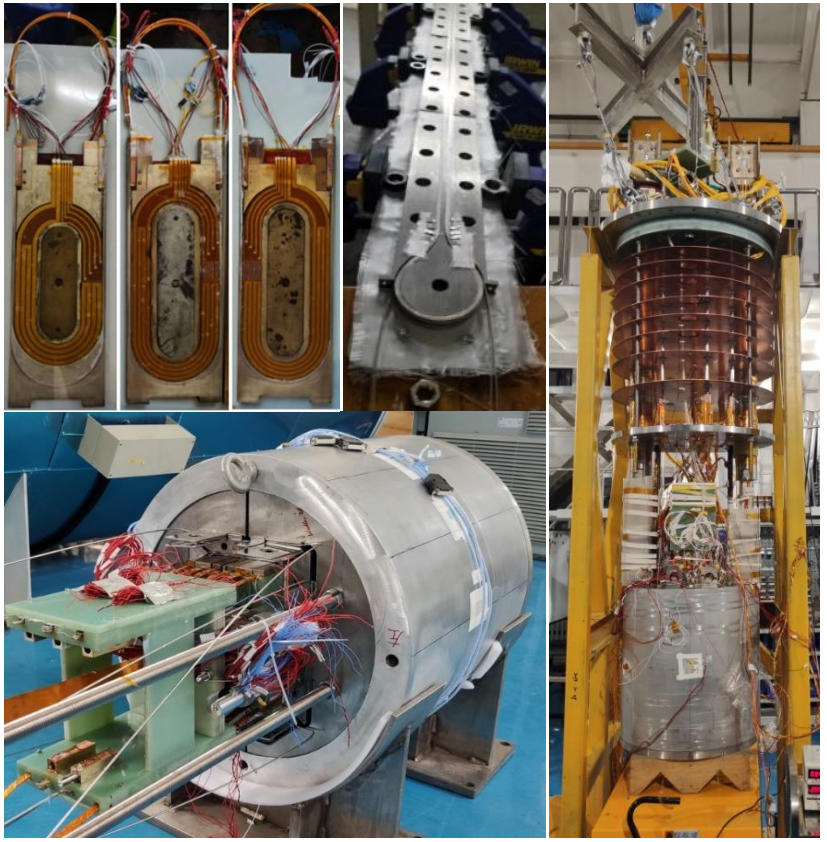
Development of **NbTi+Nb_3Sn twin-aperture** model dipole magnets from 2017.
Dipole field reached **12 T @ 4.2 K** in May 2021 and **12.47 T** after a thermal cycle.



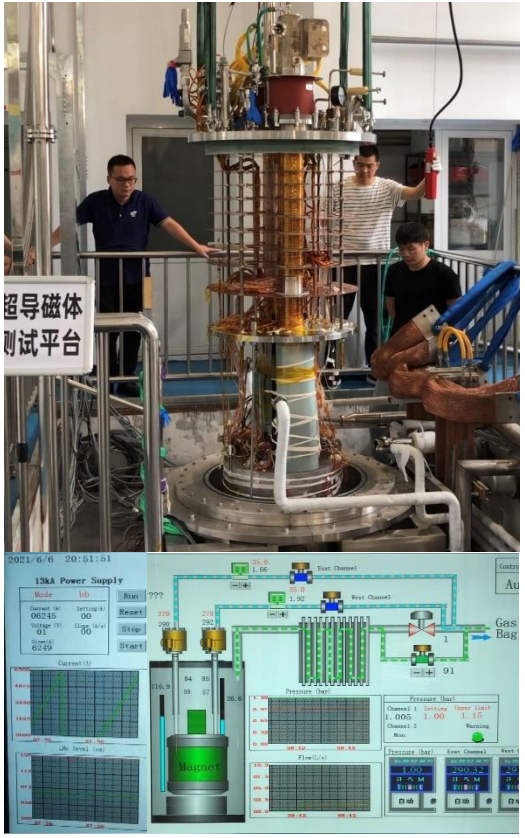


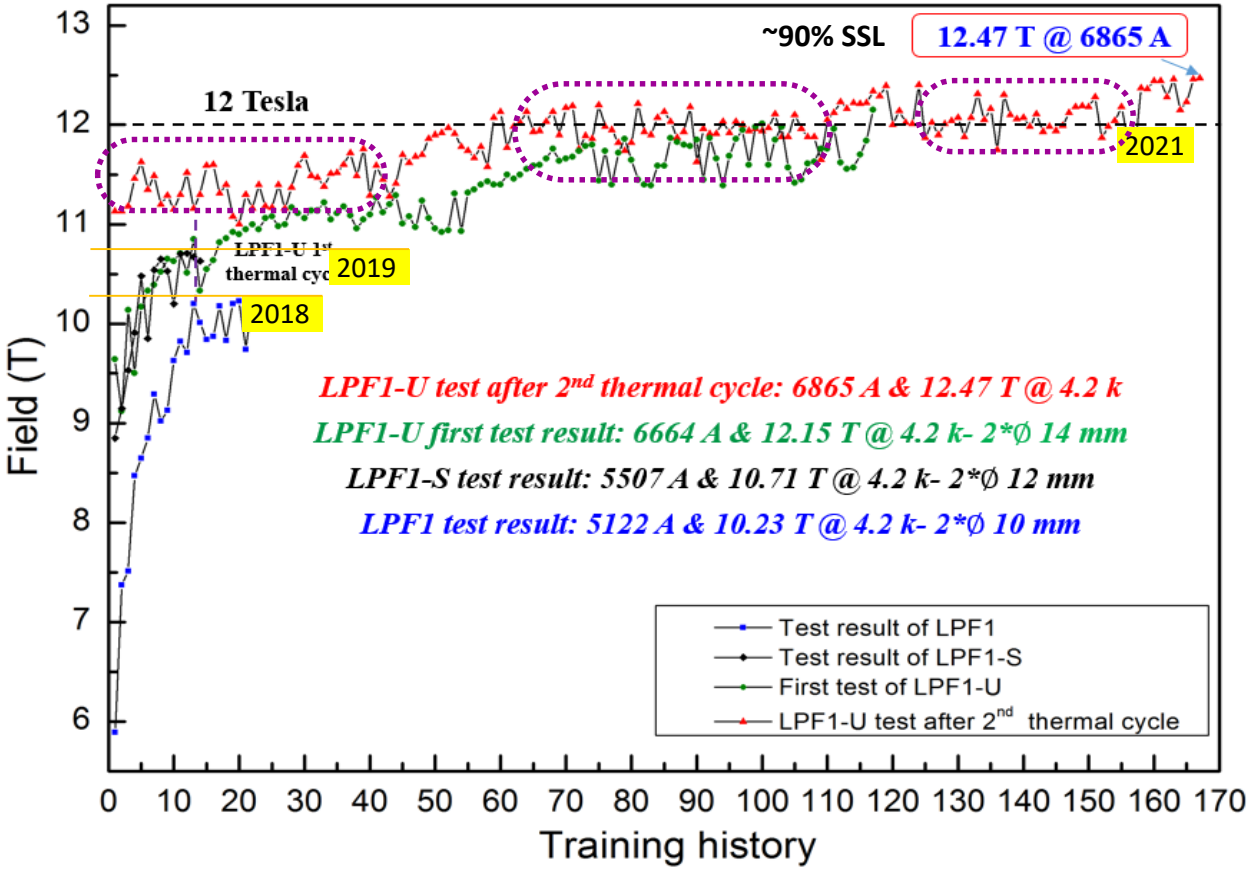






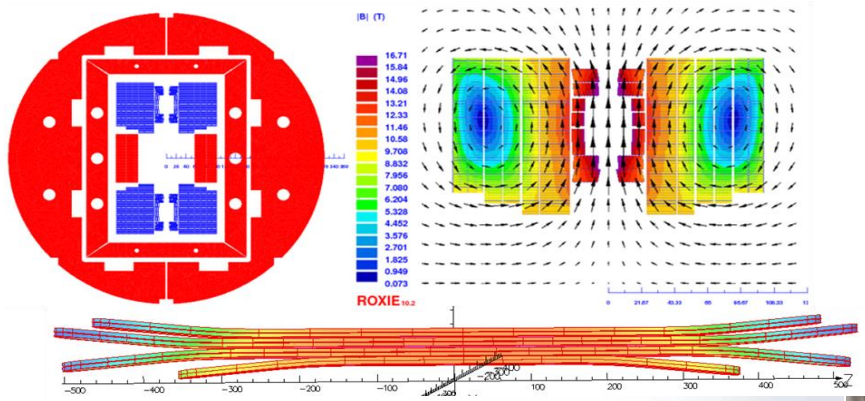
R&D of the High Field Model Dipoles

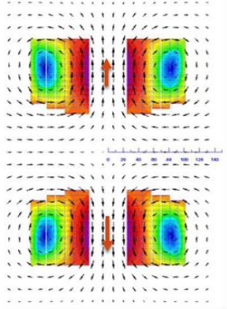


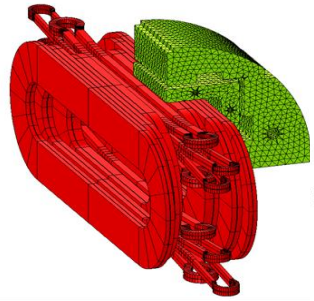


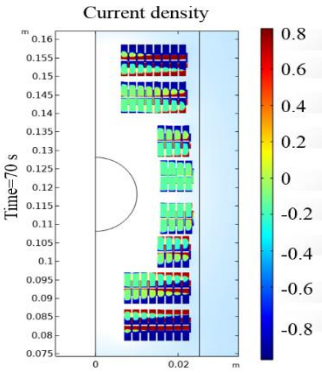
R&D of the High Field Model Dipoles

16 T Model Dipole: Nb_3Sn 12~13 T + HTS 3~4 T

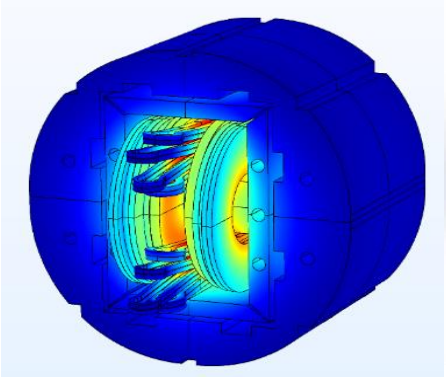


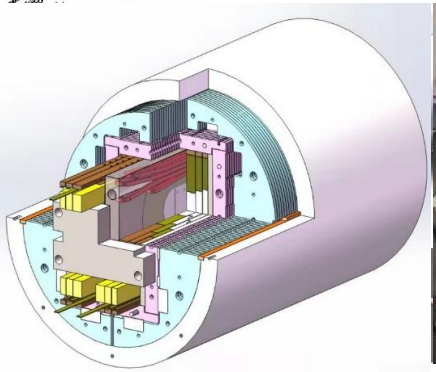


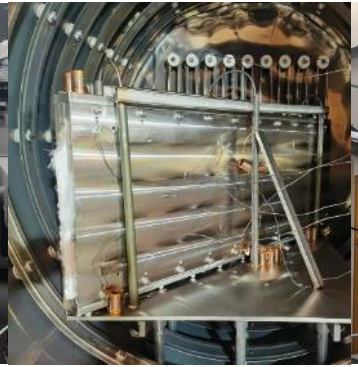




16-T 大孔径高场超导二极磁体 LPF3 (Nb_3Sn-13



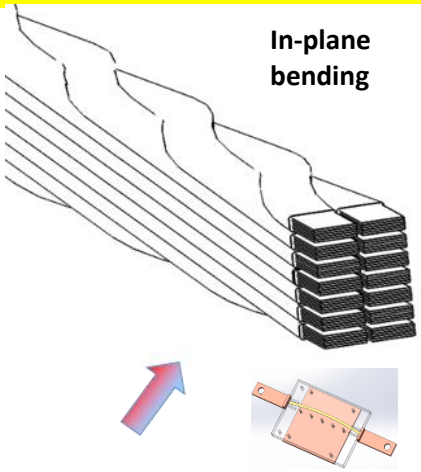


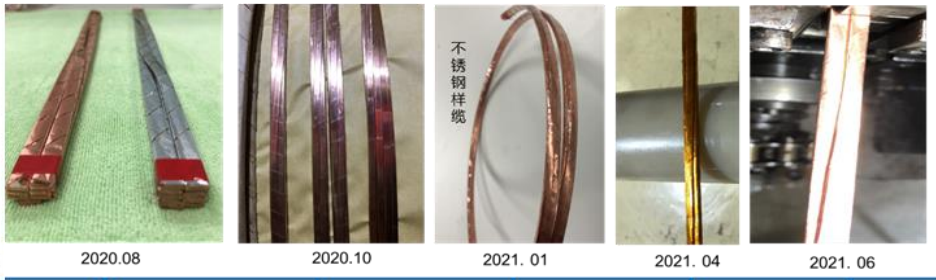


R&D of the High Field Model Dipoles

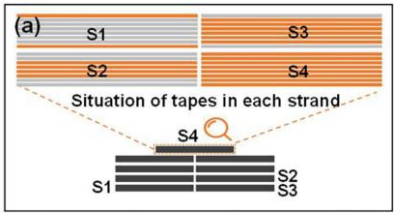
Development of a Roebel-like HTS Cable with the in-plane bending ReBCO tapes

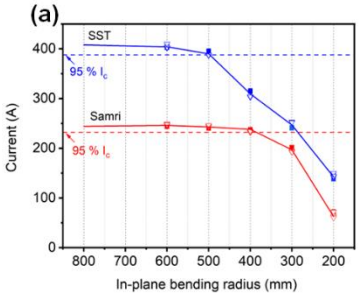
J. Wang et al, *Superconductivity* 3 (2022) 100019

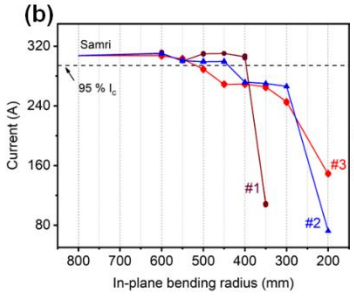


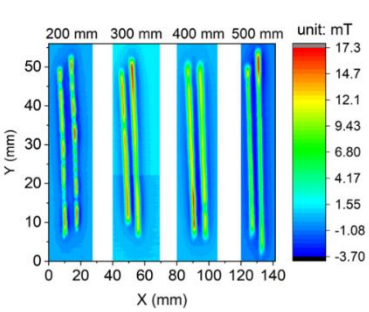


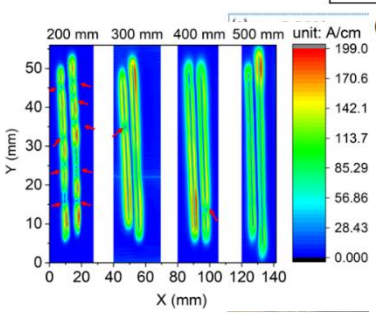
- 10-m prototype cable fabricated
- **Cable current reached 2000 A**
- Most of the tapes extracted from the cable showed no degradation.
- High field coils wound with the cable to be fabricated and tested

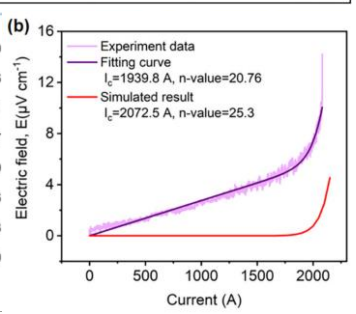












R&D of the High Field Model Dipoles

Roadmap for future

Field (T)

20

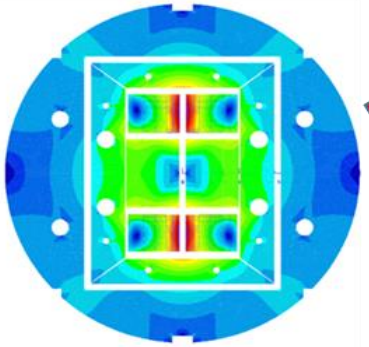
10

2018

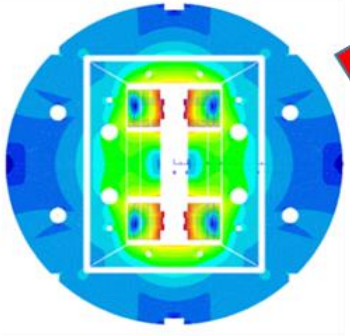
2028

year

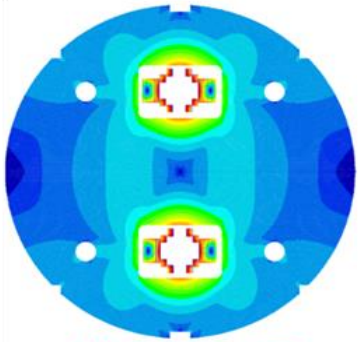
NbTi+Nb_3Sn
2*ϕ10 aperture
10T @ 4.2K



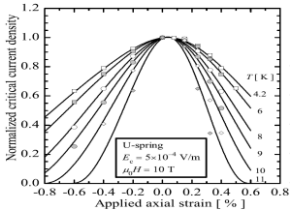
Nb_3Sn+HTS
2*ϕ30 aperture
15T @ 4.2K



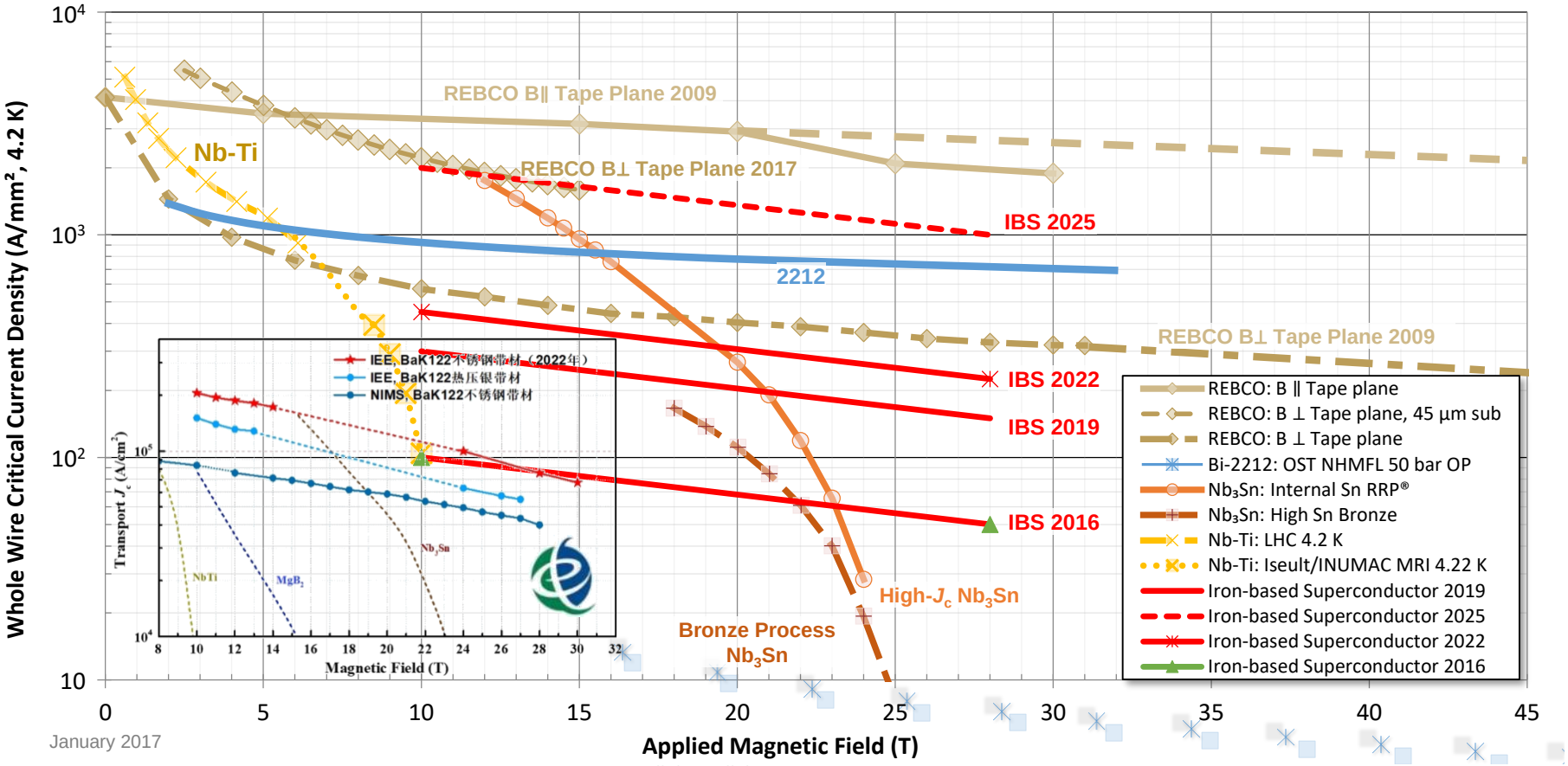
Nb_3Sn+HTS or HTS
2*ϕ45 aperture
20T @ 4.2K
With 10^{-4} field quality



Challenges: Stress control, quench protection, field quality control,……



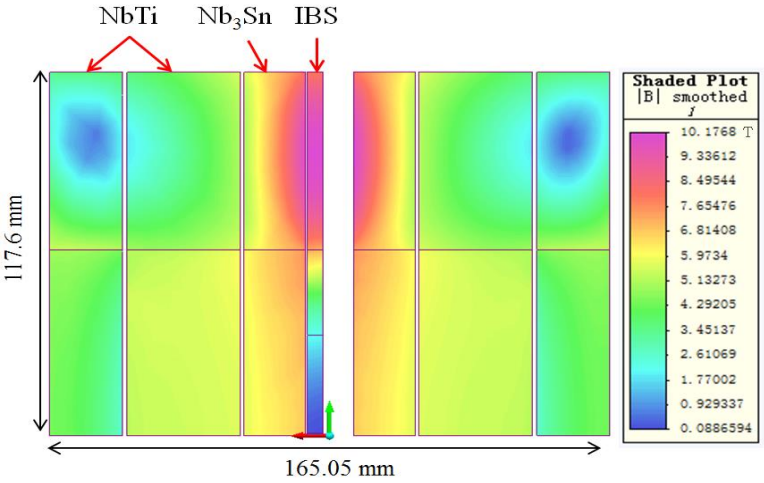
IBS Technology: Status and Outlook

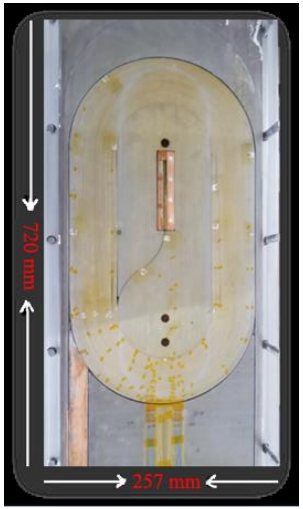


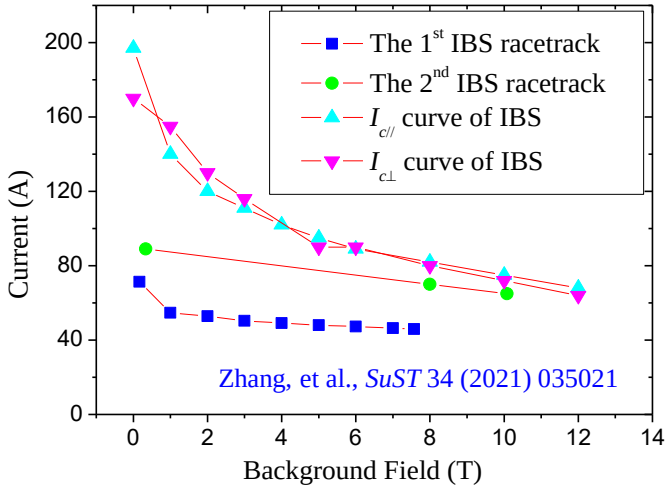
IBS Technology: Status and Outlook

Racetrack Coils with 100-m Long IBS Tape

- Two racetrack coils have been made using the 100 m length IBS tapes.
- The coils reached 86.7% of critical current of the short sample at 4.2 K and 10 T.
- with highest compressive stress of 120 MPa.







Comments from SUST reviewers:

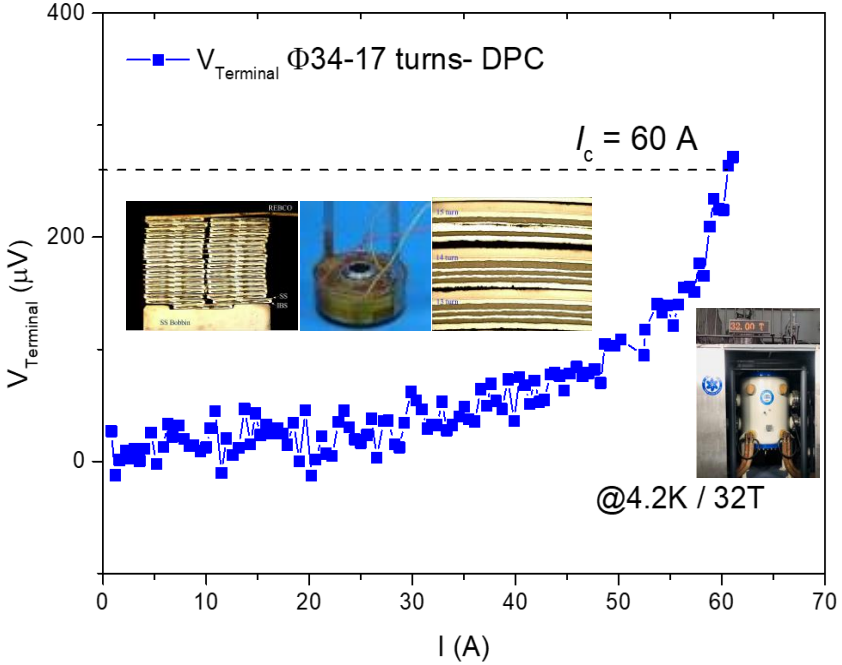
a) ...the new results that can have a strong impact on the conductor and magnet community.

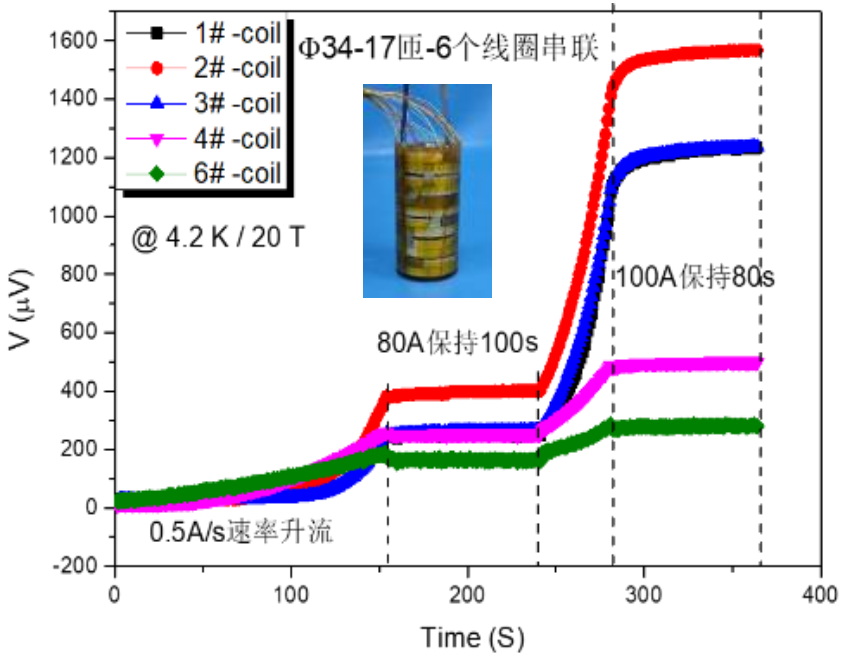
b) ...demonstrated the great potential of Iron-Based Superconductor in the development of next-generation accelerators.

IBS Technology: Status and Outlook

First IBS Solenoid Coil at 32 T background field

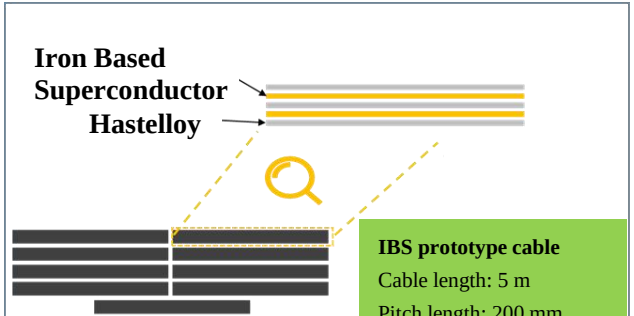
I_c of Φ34mm-17 turns-DPC reached **60 A at 4.2 K and 32 T**



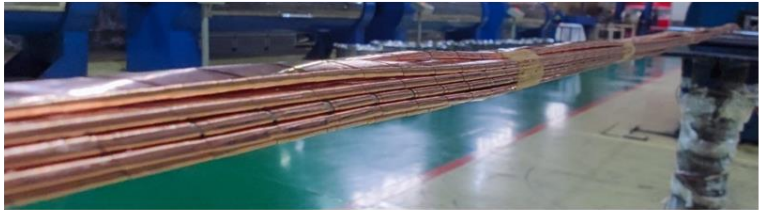


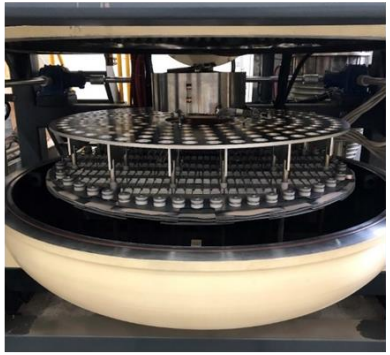
IBS Technology: Status and Outlook

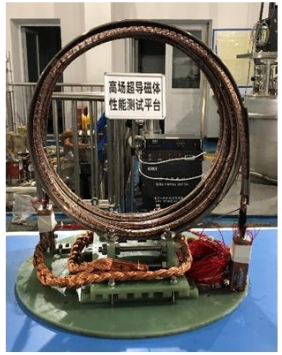
Development of a Roebel-like HTS Transposed Cable - IBS

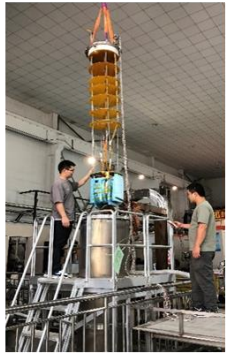


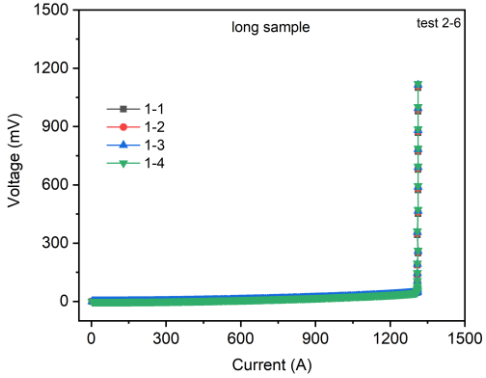
IBS prototype cable
Cable length: 5 m
Pitch length: 200 mm
Cable thickness: 10.5 mm
Current：>1300 A





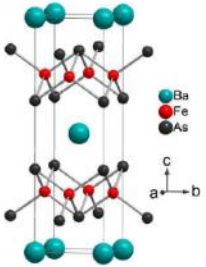




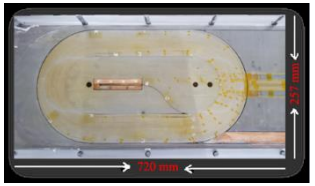


IBS Technology: Status and Outlook

Z. Zhao
IBS (T_c 55K)



100-m 7-core IBS tape fabricated
J_e= 100 A/mm^2
@ 10 T, 4.2 K



IBS solenoid at 32 T
Racetrack at 10 T
J_e > 450 A/mm^2
@ 10 T, 4.2 K

2008.02 Discovery of IBS

2008.04

2008.09 Discovery of 122 phase IBS

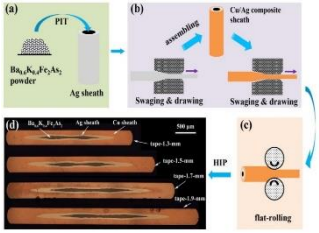
2016

2018

2020

2022

H. Hosono
IBS (T_c 26K)



IBS solenoid at 24 T
Racetrack at 8 T
J_e= 300 A/mm^2
@ 10 T, 4.2 K

J_e of IBS expected to be similar as ReBCO in 5 years with better mechanical properties and lower cost

Summary

- *Long-term advanced superconducting magnet R&D for future high-energy accelerators is ongoing at IHEP-CAS.*
- *Capture solenoid model magnet for EMuS is under development, and 14 T solenoid for MOMENT project to be developed in future.*
- *10+ T twin-aperture model dipoles being developed at IHEP, reached 12.47 T at 4.2 K in 2021. 16 T (Nb_3Sn+HTS) model dipole under development, and to be tested in 2023.*
- *R&D of the Iron-Based Superconducting technology ongoing. SS stabilized IBS tape achieved the highest J_e in 2022, expected to be competitive with ReBCO in 5 years, but having better mechanical properties and much lower cost.*

Thanks for your attention!